MAGNETORESISTANCE IN SEMICONDUCTOR-METAL HYBRIDS

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ABSTRACT

Extraordinary magnetoresistance (EMR) in semiconductor-metal hybrids has been studied exclusively for sensor applications. However, some properties of EMR-based devices are potentially advantageous for power applications. A PSPICE finite-element model has been developed to aid in the analysis and design of semiconductor-metal hybrid devices for power applications. This paper presents the model theory, implementation, and results when applied to an externally-shunted van der Pauw (vdP) plate. The conventional 4-terminal (4-point) vdP probe configuration for sensors is compared to 2-terminal (2-point) probe positioning which is necessary for power devices. The effects of material properties on resistance and magnetoresistance (MR) for an externally-shunted vdP plate in both probe configurations are presented.

Two prototype metal-semiconductor hybrid topologies for power applications have been derived from EMR sensor technology and are examined here for the first time, the shunted Corbino plate (SCP) and the externally-shunted Hall plate (ESHP). The PSPICE FEM model was used to analyze MR behavior as a function of geometric ratios characteristic of each new topology and semiconductor material properties. Sets of models for each topology generated using ElecNET were used to evaluate these devices' pulsed-current and breakdown limitations.

The PSPICE model has the benefit of being versatile, simple, and computationally stable. Understanding the 2-point resistance behavior of existing EMR sensors is a primary step in characterizing EMR-based power devices since it, and not the conventional 4-point resistance, is of merit for power applications.

The largest room-temperature MR ($\Delta R/R_o$) calculated for each prototype topology was approximately 2000% at 1 T. Current concentration caused by the inclusion of a shunt was found to limit the pulsed current capacity in each device studied. For a common scale (13.6 mm x 3.4 mm x 1 mm), pulsed-current capacity was found to vary within each device topology according to a characteristic geometric ratio. The best candidate, in terms of MR, from the SCP family showed a 1-ms pulsed current capacity of 323 A. In contrast, the pulsed current capacity of the best ESHP device was found to be 82 A. The best device geometries in terms of MR showed the lowest breakdown voltage among each set, both ~ 200 V. The data set presented here is useful for purely characterization purposes. But also, these findings and the unavoidable trade-off between magnetic sensitivity and breakdown voltage indicate that potential advantages are offset by intrinsic limitations in the use of the EMR effect for power applications.